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Experimental Evaluation of the Mechanical Properties of Coconut Fibre-Epoxy Resin Composite for Vibration Damping

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ABSTRACT

The interference of industrial facility equipment vibration and noise with residential buildings cannot be overemphasized. The beneficiation of natural fibre had been a subject of discussion and coconut fibre was sufficiently available for beneficiation. This has led to the investigation of the application of the coconut matrix composite material for the design of passive vibration damper. Therefore, this study focuses on investigating the potential of coconut-polyurethane composite for vibration control in structure vibration. This involved using hand lay-up and press moulding with a hydraulic machine to produce the composite and specimen test, while the specimens are subjected to mechanical tests to evaluate the mechanical properties of the composite towards manipulating the properties for suitable composite development for vibration damper. The findings showed that mechanical properties are associated a great deal with the dynamic characteristics, mechanical properties of the composites such as micro-hardness, tensile strength, flexural strength, and impact strength among others are greatly influenced by the fibre lengths, dynamic characteristics such as natural frequency can be predicted by analysing the Mechanical Properties. It is observed from the experiment that a natural coconut coir fibre matrix is best suitable for Structural and non-structural applications.

KEYWORDS: Coconut-coir, natural fibre, vibration, damper, epoxy resin

I. INTRODUCTION

The Lagos state government in recent time focused on building integrity test because of the frequent cases of building collapse within the state. In Lagos state, there has not been a clear-cut demarcation of industrial facility and residential facility. The interference of industrial facility equipment vibration and noise with residential building cannot be overemphasized. These include the use of reciprocating machines and industrial generators which causes vibration transmission through the ground onto building foundations. Dynamic and structural systems often encounter undesirable vibration which could be controlled to avoid failure or breakdown and instilled the possibility increase system lifetime. It therefore becomes necessary to control the vibration emanating from such machines and or attenuating the vibration absorbed by the surrounding buildings. Developing vibration damper using natural fibres had been a subject of focus for some time now [1-3]

Coconut Coir is a natural fibre extracted from husk of coconut. The coir is found between the hard internal shell of the coconut and its outer coat and had been successfully used for the development of floor mats, brushes, insulations, packages and had served as reinforcement materials in thermo-set and thermoplastic production among some other application [4-6].Using natural fibres such as coconut fibre as reinforced composite in recent time is a focus of discuss in replacing the inorganic reinforcement [7][8].

was able to obtain dynamic and static properties of a proposed combined polymer composite which consist of a polyester matrix and coconut fibres was investigated in [9][10]. The influence of fibres volume on the mechanical properties was also evaluated. Tensile test was done to know the material's strength by using Universal Testing Machine. The results indicates that the tensile modulus changes with the fibre coconut. The strength of coconut fibre reinforced composites decrease with the amount of fibre indicates non-effective stress transfer between the fibre and matrix. The conclusions were found that the mechanical properties have a strong association with the dynamic characteristic and the damping ratio was found decreasing by incorporation of natural fibres, given merit to the structure in reducing the high resonant.

The investigation which centred on the use of natural fibres such as coconut fibres is industrially encouraging because of its low-cost, high availability and desired mechanical properties for some applications, such as panels, ceilings, and partition boards and automotive components [11]. Furthermore, polymers with coconut fibre composites were made by infusion handling and precisely described by elastic and dynamic testing. Dynamic test was carried out to the composites based on natural fibre polypropylene that the increase in fibre content reduces the loss factor, storage factor and loss modulus. The elastic modulus values that the stress- strain test was compared. The Dynamic method used measure the elastic modulus for coconut fibre-pp composites was revealed as a non-destructive method and dependable test. Also, properties of random discontinuous natural fibre reinforced composites by systematic and statistical method were evaluated in Esfandin[12]. Composites based on polypropylene and reinforced with natural fibres were made and their mechanical properties were measured together with the distribution of the fibre size and the fibre diameter.

Natural fibres composite had been found to present some advantages over other composites like low-cost and malleability as discussed in Gelfuso [13].The areas of application of composites have grown rapidly over the years and even found new markets. They’ve proven their worth in weight saving, the current challenge is to make them durable and cool effective. This has resulted in many new techniques currently being used in the industry in areas like the transport sector, composite device to reduce, even support beam of bridges, and repair of seismic activity. While composite has vast applications, its selection will depend on factor such as working life, lifetime requirement, complexity of product, shape, number of items to be produced, savings in terms of cost and experience and skill of designer to trap optimum skill of the composite. Gelfuso *et al.*[11]studied the composite of polymers and coconut fibre composites. The composite was made by injection processing and mechanical test carried out. The young’s modulus parameters obtained was found to reduce with the load applied on the fibre. The elastic modulus values were obtained by the half –power bend method and the stress- strain test was compared. A portion of these properties like modulus, damping factor, among others. The review was to explain the viscoelastic properties of composites dependent on polypropylene network with various measure of coconut fibres by estimating damping factor, misfortune factor, Storage modulus, misfortune modulus and complex modulus dependent on trial and numerical computations.

Konduru*et al.*[14]established that coconut coir dust (CD) is an alternative substrate component for materials such as paper sludge, coal bottom ash, shredded rubber because some of these materials are not produced in large enough volumes to influence the market, and others are highly variable and many contain undesirable materials e.g., mercury, lead, metal fragments and glass. Coir dust has been demonstrated to be suitable for use in substrates via numerous production trials and it has been reported that the properties were generally within acceptable ranges except for electrical conductivity and chloride, which often exceeded recommended levels.The environmental merits of natural filers include decreased dependence on non-renewable materials sources, lower pollution and green house emission.

The volume fraction of the natural fibre has a vital effect on the composite strength where the composite strength rises proportionally with the volume fraction increment. The need for composite material development engineering application using coir could be a subtle opportunity for weight saving materials with quality durability, toughness, and cost effectiveness [15]. Gelfuso [13] has established the possibility of the use of coconut fibre for vibration damping. The study performs dynamic test on composite based on coconut fibre-polypropylene and deduced that that the increase in fibre content reduces the Loss Factor, Loss modulus and Storage Factor. This behaviour was attributed to lower elastic modulus of the fibre.

Coconut fibre is separated from the external shell of a coconut. There are two kinds of coconut fibres, brown fibre separated from mature coconuts and white fibres extricated from juvenile coconuts. Earthy coloured fibres are thick, solid and have high scraped spot opposition. White fibres are smoother and better, yet in addition more vulnerable. Coconut fibres are industrially accessible in three structures, specifically Bristle (long fibres), bedding (moderately short) and decorticated (blended fibres). The diverse kind of fibres relies on the prerequisite. In designing, Brown fibres are for the most part utilized. These days, the needfulness of natural fibres supported composites is acquiring popularity in auto, corrective, and plastic wood applications since it gives a practical and ecological benefit over conventional inorganic fortifications and fillers. The impact of coir fibres volume division on mechanical properties and dynamic qualities of composite were definite. The outcomes indicates that the mechanical properties have a store relationship with the unique attributes. Both properties are for the most part reliant upon the volume % of fibres. Dynamic attributes, for example, natural recurrence of

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composite can be anticipated by examining the mechanical properties. The elasticity of composite viewed as immediate corresponding to natural recurrence.

Glowacki *et al.*[16] investigated on the possibilities of applying coconut husk in fire board production. The objective is to reduce the amount of phenol for maldehyde – resin in highly water resistance fire boards such as high-pressure laminates. During the cause of the study, the milling process of coconut husk was analysed, tested and verified. Ali [17] studied the adaptability of coconut fibres and its applications in various parts of designing, especially in structural designing as a development material.

The use of coconut fibre composite as a supposed hybrid material could be a breakthrough for the design of vibration control devices. Processing of Coconut Fibre.

Stephano and Galdius[18] examined the mechanical properties effect on the behaviour of hybrid composite material and tensile strength and effect on chemical test were made on the hybrid composite material containing coconut coir and nylon mat as reinforcement materials on epoxy resin matrix. The hybrid composite was prepared using hand layup technique which was very easy. The hydrophilic nature of natural fibre materials because of the presence of lignin and pectin causes adverse effects. It results in issues with adhesion with polymers and reduces the mechanical properties of the produced composite material. Chemical treatment can improve the adhesion between natural fibres and polymers. The rigidity of composite material with palm fibre treated with Sodium Hydroxide was higher than the composite example which was not exposed to any treatment.

Kong *et al.*[19]fabricated natural fibre reinforced polymer composites by integrating poly(vinyl alcohol) with treated and untreated coconut fibre, and to characterize the treated and untreated composites samples with Scanning electron microscopy, Thermogravimetric analysis, tensile test, hardness test, and moisture absorption-desorption experiment. The result of the test carried out showed that Young's modulus and other mechanical properties were significantly improved with increment of fibre volume fraction Compared to the untreated fibre. In order to produce composites with low moisture sensitivity, high degradation temperature, high hardness, high young's modulus, fibre with high content of alkali was used.

Kumar *et al.*[20]assessed the mechanical properties of coir fibre reinforced composites with different weight fraction of fibre. Coir fibre and epoxy polymer were used to prepare composites and experimental investigation are done on the composite with varied proportion of coir fibres and the effect of different weight fraction of coir fibre on tensile properties, impact strength and hardness property of specimens was analysed

The Polyurethane is an elastomeric polymer occurring in different format such as rubber. There are two types of polyurethane material are the polyester and the polyether. Polyurethane is widely used either as flexible polyurethane foam, rigid polyurethane foam, polyurethane ionomers, or thermoplastic polyurethane [21]. These applications are found in automotive industry, home appliances, including building and construction. The properties of polyurethane (PU) could be soft, in rubber forms or rigid thermoplastic and thermoset materials [22]. Their application is based on their relationship between their structure and properties.

The characterization and formation of polyurethane (PU) foam was discussed in Moises 2010. The polyurethane is used to produce a large number of products. Its application as fibres and elastomers should be well explored in vibration damper application; it is a versatile material. The chemistry types and synthesis of the PU of different types are well discussed in Akindoyo *et al*. [21].

The evaluation of the mechanical properties of polyurethane powder using suspension and dispersion polymerization have found application in Automobile, printing rollers solid PU plasticand fibre grating [23].

II. MATERIALS AND METHODS

2.1 Preparation of coconut fibre composite specimen for tests

The coconut husk was soaked in water for easy separation of the fibres. 30g of the fibres were soaked in 100g of alkali solution and washed with distilled water after which allowed to dry for 24 h to ascertain total removal of the moisture contents. A total of thirty (30) numbers of specimens were produced with 5-, 10- and 15-mm length of fibre contents. The materials were prepared in composite of epoxy resin hardened with araldite and moulded. Specimen sizes of 250 x 25 x 3 mm were prepared by the D 3039 standard of the ASTM.Coconut fibres were removed from the exocarp of the coconut and dried at 50^{o}C for 24 h. The fibre was sorted and lined in regular weights to ensure adhesion between the fibre and the matrix. The controlfibre specimen was treated with alkaline solution 1% (w/v) and washed with distilled water then dried for 24 h at a temperature of 75^{o}C.

The epoxy resin was manuallymixed, and the coconut fibre species added to form the fibre-resin laminate which serves as the coconut fibre control composite. The specimens for the control laminate were prepared as shown in Table 1.

2.2 Tensile and compressive tests of the coconut fibre

The ASTM standard (D3039) is commonly used for fibre tensile test and thus it is suitable for the fabricated test specimen made of coconut fibre and epoxy resin.

The testing machine used was the Instron® 3369 testing machine which has a 50 kN load capacity. The crosshead speed was 1.0 mm/min on both tensile and compressive tests. In the tensile test, the extensometer of 50mm gage length and the strain gages of 2 mm gage length were used for strain measurement. In the compressive test, strain gages of 2 mm gage length were used. Compressive tests were carried out for the resin and the resin polyurethane foam combination with the coconut fibre. A support jig of ASTM D 695-90 type was used for the compressive tests to avoid out-of-plane buckling failures. The specimen configuration is as shown in Plate1. Strips of material with defined dimensions prepared for the tests were anchored one after the other at one end and subjected to gradual increase in axial load. The gradual increment of the load resulted in the axial deflection of the loaded end which increased with respect to the load value and eventually with continuous loading.

Table 1: Designation of work piece

Designation	Composition
C_{55}	50% Coconutfibre + 50% Epoxy
C_{54}	50% Coconutfibre + 45% Epoxy + 5% Flyash
C_{53}	50% Coconutfibre + 40% Epoxy + 10% Flyash
C_{52}	50% Coconutfibre + 35% Epoxy + 15% Flyash
C_{51}	50% Coconutfibre + 30% Epoxy + 20% Flyash

Plate 1: Test piece configuration

All the composite test piece were tested in a compression testing machine to determine static modulus of elasticity E_s, compressive strength σ_c, corresponding strain ε, compressive toughness Tc and tensile strength σ_t. All the composite test piece were tested in a universal testing machine of capacity 50 kN using 4-point loads to obtain modulus of rupture MOR, corresponding deflection D, and flexural toughness T_f

The stiffness of the material is obtained by normalizing the load by the original length of the specimen using the equation (1).

$$E = \sigma/\delta l \tag{1}$$

Where: σ is the material strain which measures the stiffness of the material, δ is the material deformation and l is the length of the specimen.

2.3 Charpy impact test

Specimen were cut according to ASTM D638 standard from the laminate in form of beams of length 140 mm with 40 mm x 7 mm x 17 mm test region. The specimen were clamped in the bench vice in the form of cantilever beam of span 140 mm

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and impact test carried out. The relative toughness for the different specimens of the composite laminate were determined from the Charpy-impact tests. A v-notch cut was made on every example utilizing a Hounsfield indenting machine guaranteeing that the indent screw is set at a profundity of 1 mm so the shaper simply contacts the test piece. Each test piece was broken with a pendulum on the Hounsfield adjusted effect machine and the energy consumed in cracking was obtained.

III. RESULTS AND DISCUSSION

Figure 1-4 shows the correlation between the load and the deflection of the fibre composites. Figure4 is a measure of the material stiffness as a response to the deflections due to the applied load.

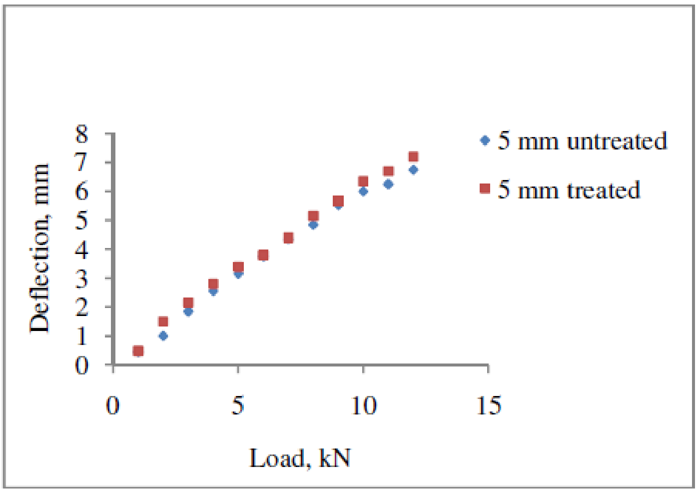

Figure 1: Load-Extension Relationship for 5 mm Fibre Length Content

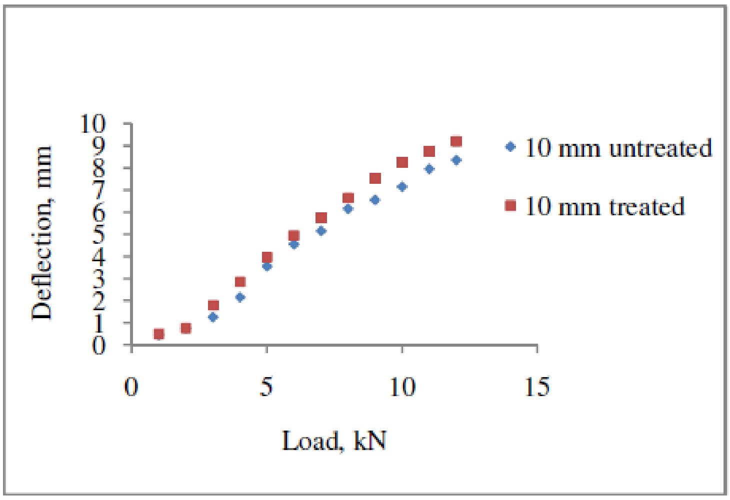

Figure2: Load-Extension Relationship For 10 mm Fibre Length Content

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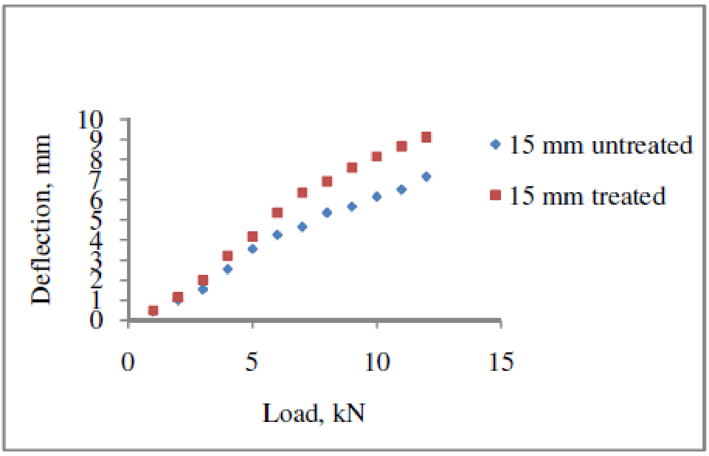

Figure3 Load-Extension Relationship for 15 mm Fibre Length Content

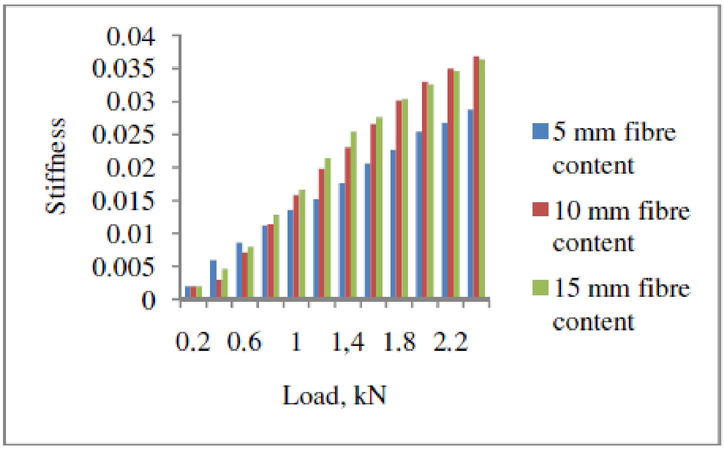

Figure4: Influence of Service Load and Fibre Length on Stiffnessof Coconut Coir.

3.1 Influence of the length of fibre on ductility

The fibre deflection is associated with the ductility of the material was observed in other materials. The figures shows that the ductility of the composite is significantly influence by the increasing length of the fibre content. The material redirection proportion is more in the treated fibre contrasted and the untreated fibre. This is anyway not very much articulated in the 5mm fibre content. The 10mm fibre content shows a significantimprovement in its ductility, and more is observed for the 15mm fibre content as explicitly shown in Figure2. It is ascertained that increasing length of the material encourages strength reducing flaws which could be associated with its ductility thus making the material more likely to be good for vibration absorbing. There is however the likelihood that the material becomes weaker due to the flaws.

3.2 Influence of service load on the stiffness of the material

The material's stiffness describes its fracture related failure. It could be inferred in Figure4 that the material's stiffness improved with increasing service load for the three categories of the material fibre contents, however at higher fibre content, there is no distinct variation in the material stiffness. This could be because of the likely disorientation of the fibre structure due to increasing strain. The trail is likely to place an optimum fibre content on such developed material, which means that further increment in the fibre length content of the material will not influence the material stiffness.

3.3 Tensile Properties of the Composite

The anisotropic property distributions for the composite laminate (Table 1) shows that the property averaging schemes depend on the orientation of the fibre phase. This implies composite material anisotropic nature.The table shows that the tensile strength of the composite with fibre orientation of 30 deg. was higher than that of the other orientation which could be due to the low tensile strength of the interleaf.

Table 1: Anisotropic property distribution for coconut fibre composite laminate

Anisotropic Direction	Load at Maximum Tensile stress (N)	Tensile strain at Maximum Tensile stress (mm/mm)	Tensile extension at Maximum Tensile stress (mm)	Energy at Maximum Tensile stress (J)	Tensile stress at Break (Standard) (MPa)
0 deg	297.6813	0.01791	0.7165	0.074	2.2238
30 deg	1162.458	0.02562	1.02481	0.52442	9.69909
35 deg	413.6841	0.02104	0.84156	0.13208	1.40134
40 deg	454.4509	0.01791	0.71637	0.14071	2.44916
45 deg	1043.177	0.01917	0.76687	0.2698	8.76619

It could be observed that the tensile properties of the composite fibre improved with increasing weight fraction of the reinforcement as shown in Figure5.

The energy absorbing capacity of the composite for dynamically loaded structure such as the lathe machine in cutting process is shown in figures 6-9. The energy absorption is dependent of the weight fraction of the fibre content. How much load the fibre can carry could depends on the interfacial bond between the fibre and the reinforcement.

The variability in the fracture strength and compression test analysis exposes the possibility of the limitation of the composite components which will require the process of optimization. However, it was observed that the ultimate strength and the fracture strain of the compressive test are higher than those of the tensile test.

Analysis shows that the composite with 35 % weight fraction of epoxy tends to have more dynamical characteristic compared with the other specimen an indication of greater damping properties of the material.

IV. CONCLUSION

Excessive vibration usually occurs in operating machines whose natural frequency amcidy with the frequency of the external excitation of the machine. The vibration causes the imperfection in the production output of the machines especially finishing of the workpiece simetrim might lead to chaotic machine response which causes machine failure. Such vibrations can be attenuated by coupling a properly designed vibration dumping device with inbuilt mass-spring-damper characteristic. These devices are referred to as dynamic vibration absorbers. The sign of the vegration is on the development of a vibration absorber from coconut fibre – polyurethane laminate composite apphease for damping the entire range of troughes of the operating workship machines.

The characterization of the vibration response of the machine indicates that major excitation area affecting the machine performances on the gearbox location, machine bed location, tailstock location, and the spring chuck location.

The material deflection is well influenced by the percentage influencing coconut fibre content with the 10mm length fibre content showing significant improvement in diversity of the absorber. These prayi dising the ability of the fibre – polyurethane composite material is suitable for damping of frequency excitation. The tensile frequency of the composite material improve with increasing weight fraction of the mainprovement. The sinuation of the performance of the material shows that the composite deformation during hormonic response analysis in minimal compound in the static structural analysis

The composite laminate of the coconut fibre- polyurethane laminate was fabricated laminate using compressive test analysis was found to be in close agreement with the simulation and sufficient to arrelrence that the behavior of the laminate defines it ability to efficiently damp the frequency excitation of dynamic and static structures.

Conclusively, the result found that mechanical properties associate a great deal with the dynamic characteristics, mechanical properties of the composites such as micro- hardness, tensile strength, flexural strength, impact strength among others are greatly influenced by the fibre lengths, dynamic characteristics such as natural frequency can be predicted by analysing the Mechanical Properties.It is clearly observed from the experiment that natural coconut coir fibre matrix is best suitable for Structural and non-Structural applications.

Coconut fibres are reported as most ductile and energy absorbent materials. It is noted that coconut fibres have what it takes to be used in composites for various purposes. It is in no doubt that the Vibration control of mechanical systems by suppression or attenuation is important. Coconut fibre composite could be developed as a viscoelastic material to serve as an absorber for dynamic vibration as has been widely applied by some other viscoelastic materials. Which could be a successful approach towards beneficiation of coconut fibre as low cost and maintenance vibration attenuating material.

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